RoboCup Rescue 2024 Team Description Paper CJT-Robotics

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Info

Team Name:	CJT-Robotics
Team Institution:	CJT-Gymnasium Lauf
Team Country:	Germany
Team Leader:	Rudolph Pausenberger
Team URL:	https://cjt-robotics.github.io

***Abstract*—This paper describes how the robot Error 404 came to be, from a few parts to the only major rescue league robot made entirely by high school students.**

***Index Terms*—RoboCup Rescue, Team Description Paper**

I. Introduction

CJT-ROBOTICS is a team of six students from the Christoph-Jacob-Treu Gymnasium in Lauf. We are the only school team in Germany that participates in the major RoboCup tournaments and were funded in 2022. In 2023 we participated in the German Open and won the Category Small Robots. This Year we will compete again. Also, in 2023 we were on the Exhibition "Consumenta" and took part at a competition the technical university Ohm hosted and won the innovation prize. We are focused on reaching high speeds in medium to difficult terrain, and all of that with the limited budget and possibilities of a school team. We utilize six wheels in combination with a well-functioning parallelogram suspension system with fully independent wheels, which allows us to keep full ground-contact with all wheels. Our capabilities include 2D mapping, hazard sign recognition, barcode recognition, CO_2 detection and excellent offroad performance. Currently we are working on developing a robotic arm system to expand our abilities.

II. System Description

Use this section to describe your overall system. Depending on the emphasis of your team the different subsections can be of different lengths. Nevertheless please be as detailed as possible. The advantages are:

- Get qualified for RoboCup Rescue by having a detailed system description.
- Document your teams approach.
- Allow a comparison of your team with other teams.
- Allow a comparison between different years of RoboCup and thus (hopefully) a documentation of the improvements through the years.
- Allow other and especially new teams to kick-start their research by copying your system.

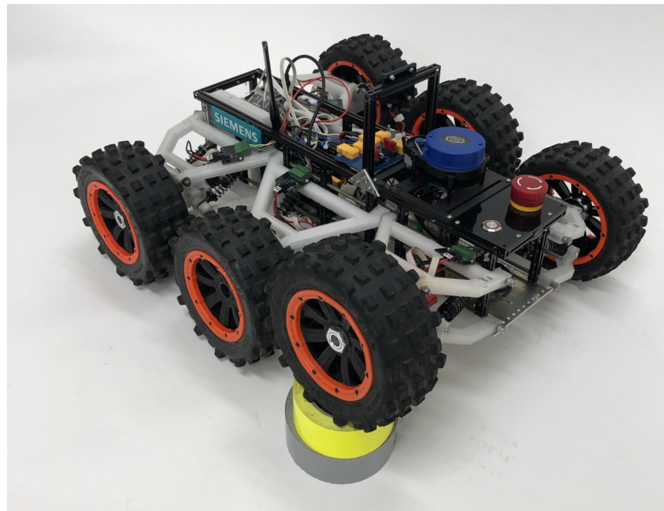

Fig. 1. Standard measuring unit: two rolls of duct tape.

A. Hardware

1) Drivetrain: Our robot utilizes a direct drive locomotion system, as every wheel has one motor attached to it. The Motors are powered by one central stack of PCBs that combine motor control and voltage regulation.

2) Power: The robot operates on mainly 24 Volts (drivetrain, arm, motor controllers), it also utilizes a 19V rail as well as a 12V and 5V rail, to power the electronics. The power is distributed via an in-house designed PCB to act as a power junction and fuse box. Our robot is powered by one Lithium-Ion battery, powerful enough to ease through 30 minutes of driving due to having a capacity of about 200 Watt hours. Two further batteries may be used in rotation to increase running time. The batteries are over-scaled for our application, in order to increase the longevity, they have a discharge rate of up to 90 Coulombs.

3) Electronics:

a) Motor Controllers: The motor controllers are placed centrally in the chassis and regulate and power the motors using PWM (Pulse With Modulation) signals. They also output a constant 12 Volts and 5 Volts to power peripherals. These PCBs were developed by Prof. Dr. rer. Nat. May.

b) IPC: We are currently using a Siemens IPC as the main controller of the robot, it is connected to the motor controllers via the OPEN CAN interface.

c) Router: Our Siemens Scalance W720 is connected to the IPC via LAN and communicates to the main Netgear via 5 Ghz.

d) Sensors: The robot uses a Light Detection And Ranging (hereafter referred as LiDAR) sensor, a CO_2 sensor, a gas composition sensor, and several ultrasonic and infrared distance sensors, both as a backup for the LiDAR in case of smoke or similar environmental disturbances that disable one or two of the sensors as well as the camera.

4) robotic arm: As for our robotic arm we will have six axis with two of them being in in the first joint, one in the second joint and three at the third between the arm and the gripper. The first and second are powered by linear actuators. For the third joint we will use three servos. Our gripper will consist out of two granular jamming grippers. They shall be mounted facing each other with the ability to open and close them. Therefore they will deform to fit the surface of any object perfectly.

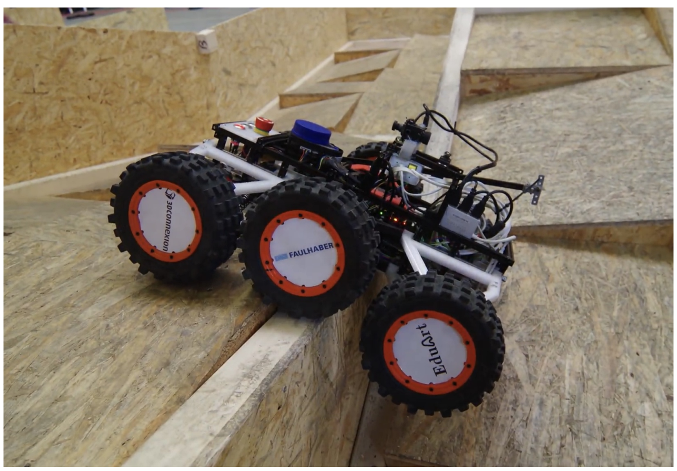

Fig. 2. Error 404 in action.

B. Software

1) GUI: In order to ease operation, we have decided to create a GUI that includes all applications needed to ensure smooth and faultless completion of the mission. It includes status data of the robot, such as the ping, the individual rpms of all six wheels, the remaining Voltage of the battery. It also displays the images from the front- and rear- cameras and processes them by checking for movement, barcodes and Landoltrings. To improve the performance, these features can be toggled.
This GUI also includes the Data of the LiDAR Sensor as a two-dimensional plane of the current situation. Distances between the robot and objects can be displayed to give a better feel of the environment.
We are using the Hector Slam Package to create a map of the environment. Currently we cannot use this map to drive autonomously but it is one of our first priorities.

2) Movement Detection: The motion detection application is based on the subtraction between two images. To highlight the objects effectively, only the contours are subtracted from each other in the images.

3) Unknown Picture Detection: One challenge of the competition last year was to analyze and assign unknown pictures. The difficulty is that none of the teams have prior knowledge of what pictures will be selected for the competition. Hence, we must train our programs on site in a small amount of time. Due to our focus on other competitions, we have not brought any application with us. In a short amount of time, an application was made, that could recognize the images, by comparing the average red, green and blue values of the pixels. This was possible, since a white sheet of paper served as a consistent background. (no comment, it worked)

4) robotic arm: The robotic arm ist controlled by a mostly complete inverse kinematics script that calculates the angle of each joint in order to reach a predefined destination. In the event that this is not enough, each joint can be rotated seperatly.

C. Communication

The communcation between the robot and the notebook ist established with a 5G wifi network.
We are using the Netgear Nighthawk X8 AC5300 Tri-Band WiFi Router
as well as the Siemens Scalence W761-1 on the robot.
The Netgear Router has internal antennas and runs on ddwrt, while the Siemens Scalence is supported with an external antenna and uses the standard OS. We are using the default Protocol ROSTCP and plan on using the SSID "RRL_CJT-Robotics_5Ghz".

D. Human-Robot Interface

As already mentioned in software, the operator has the option to use a camera pointing towards the front aswell as one to the rear side. They get additional data in the form of the 2D-plane of the LiDAR and the rpm-values of the wheels. The robot is controlled with a Logitech Joystick.
Our operator enjoys playing simulator games in his freetime so he already had some expierence in piloting remote vehicles. The training on the robot happened by creating a small obstacle course with some spare wodden planks and wide steps in our school.
We suggest, that a user should start by driving on a level floor to get a feeling for the turns and velocity, they could than turn around and start piloting by using only the data provided by the robot. As soon as this works reliably the user could swich to an obstacle course. We would advise to start by keeping eyesight on the robot and switch to remote control after a couple of rounds through this course.

III. Application

A. Set-up and Break-Down

1) Set-up: Setting up the robot is fairly straightforward, since we have created one roslaunch file that launches all necessary nodes on the robot and on the operator's side there is only one main GUI that must be started.

2) Break-down: The breakdown is also quite fast because the robot is light enough to be easily carried by one person.

B. Mission Strategy

Our strategy solely relies on our speed and maneuverability to get through our courses faster than our tracked competitors. Because we have tested our suspension design thoroughly, we can be sure to have an edge in that regard. The newest addition to our robot is the robot arm in combination with an experimental gripper, that will have its first competition at the German Open RRL 2024.

C. Experiments

At the Consumenta (stage of the RMRC) we ran through the typical RRL stages: elevated ramps, K-Rails, and the Gravel pit. In addition, we tried out running over rubble piles and driving up and down stairs. Another trial will be the RRL German Open from the 17. to the 21. of April. There we will have the ability to test the robotic arm to its fullest and the system in the official stages.

D. Application in the Field

Our long-term goal is to refine our system to the point that we can work with our local THW, the german crisis intervention team. It would be used for dangerous tasks, such as reconnaissance and exploration of dangerous or unknown terrain.

IV. Conclusion

Overall, our robot serves as a proof of concept for a rescue assistant, with its main advantage lying in its speed in tight, inaccessible spaces. Its low weight of only 12 kg (without arm) and rapid deployability also present significant advantages. The diverse array of sensors enables precise environmental perception. While the capabilities of Error 404 are unfortunately limited, this has not posed an issue in previous competitions. Despite not being able to navigate obstacles such as doors or stairs, its speed and precision have earned us enough points to secure victory. In the future, we aim to overcome these limitations, hence, we are introducing our arm prototype for the first time, with the capabilities we believe will enable us to tackle any challenge we encounter. We are prepared to showcase this at the 2024 World Championship.

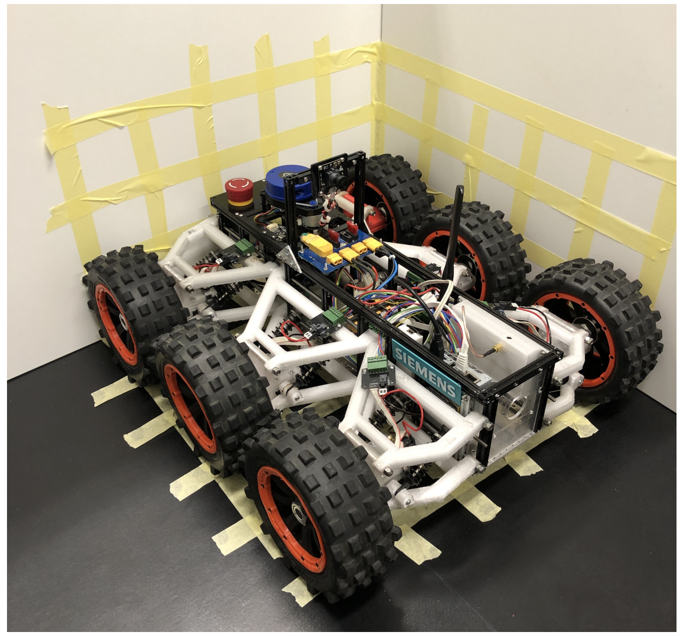

Fig. 3. Photo of our robot with the 10x10 cm grid.

Appendix A
Team members and Their Contributions

- Philipp Fischer — Software development
- Linus Gürne — Mechanical design (CAD)
- Noah Heckel — Mechanical design (CAD)
- Tim Hennig — Mechanical design
- Max Müller — Public relations
- Markus Peltsarszky — Software development

Appendix B
CAD Drawings

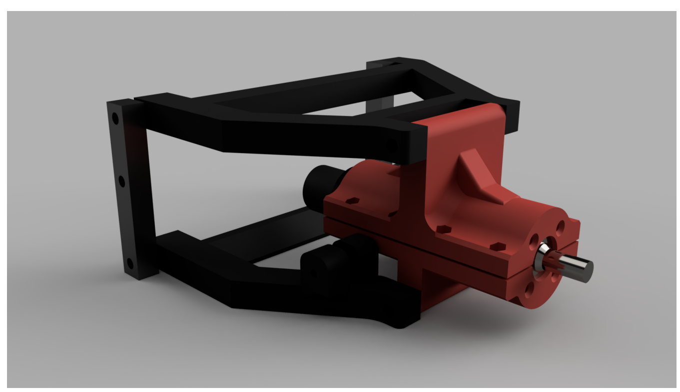

Fig. 4. CAD-Drawing of our suspension in its middle position.

Appendix C
Lists

A. Systems List

Table I

B. Hardware Components List

Table III

C. Software List

Table IV

Acknowledgment

The authors would like to thank our teacher and supporter Rudolph Pausenberger, as well as Prof. Dr. rer. Nat. May who not only designed the motor controllers and helped us where he could

References

[1] S. Kohlbrecher, J. Meyer, O. von Stryk, and U. Klingauf, "A flexible and scalable slam system with full 3d motion estimation," in *Proc. IEEE International Symposium on Safety, Security and Rescue Robotics (SSRR)*. IEEE, November 2011.

TABLE I
MANIPULATION SYSTEM

Attribute	Value
Name	Error 404
Locomotion	wheeled
System Weight	12kg
Weight including transportation case	15kg
Transportation size	0.9 x 0.7 x 0.5 m
Typical operation size	0.5 x 0.6 x 0.3 m
Unpack and assembly time	40 min
Startup time (off to full operation)	15 min
Power consumption (idle/ typical/ max)	17 / 50 / 350W
Battery endurance (idle/ normal/ heavy load)	24+ / 2 / 1hr
Maximum speed (flat/ outdoor/ rubble pile)	1.8 / 1.8 / 0.3 m/s
Payload (typical, maximum)	none
Arm: maximum operation height (work in progress)	120 cm
Arm: payload at full extend (work in progress)	2 kg
Support: set of bat. chargers total weight	3.5kg
Support: set of bat. chargers power	150W (6 - 15V DC)
Support: Charge time batteries (80%/ 100%)	90 / 120 min
Support: Additional set of batteries weight	2.5kg
Suspension Travel	8.5cm
Cost	7750 USD

TABLE II
OPERATOR STATION

Attribute	Value
Joystick	Logitech Joystick
Router	Netgear Nighthawk X8 AC5300 Tri-Band WiFi Router
Laptop	subject to change

TABLE III
SOFTWARE LIST

Name	Version	License	Usage
Ubuntu	20.04	open	
ROS	noetic	BSD	
OpenGL	4	open	GUI creation
imgui	1.89.8	MIT	GUI creation
glfw	3	Zlib	GUI creation
OpenCV	2.4.8	BSD	image evaluation
DeepHAZMAT	1	open	Hazmat detection
Hector SLAM [1]	0.3.4	BSD	2D SLAM

TABLE IV
HARDWARE COMPONENTS LIST

Quan.	Item	Notes	Price in €
6x	Faulhaber 3242G024CR + 32/3R 86:1 + IE3-1024	Drivetrain	780 [sp]
5x	Servo Motor		23
	Siemens Scalence	IoT	400 [sp]
	Antenna		10
	Antenna cable		10
	Siemens IPC nano	IoT	1034 [sp]
4x	Motorcontroller PCB		-
	DC/DC Fuse PCB		-
	USB to CAN interface		21
4x	Camera	Peripherals	54
	LiDAR	Perioherals	120
	CO_2 sensor		69
	Ultrasonic distance sensor		20
	IR distance sensor		32
	LED lights		12
12x	Spring		40
6x	Wheel 190x70		50
	Makerbeam 10mm profile est. 5m total		340
2x	3D Printed transverse lower control arm Type 1		-
2x	3D Printed transverse lower control arm Type 2		-
2x	3D Printed transverse lower control arm Type 3		-
2x	3D Printed transverse upper control arm Type 1		-
4x	3D Printed transverse upper control arm Type 2		-